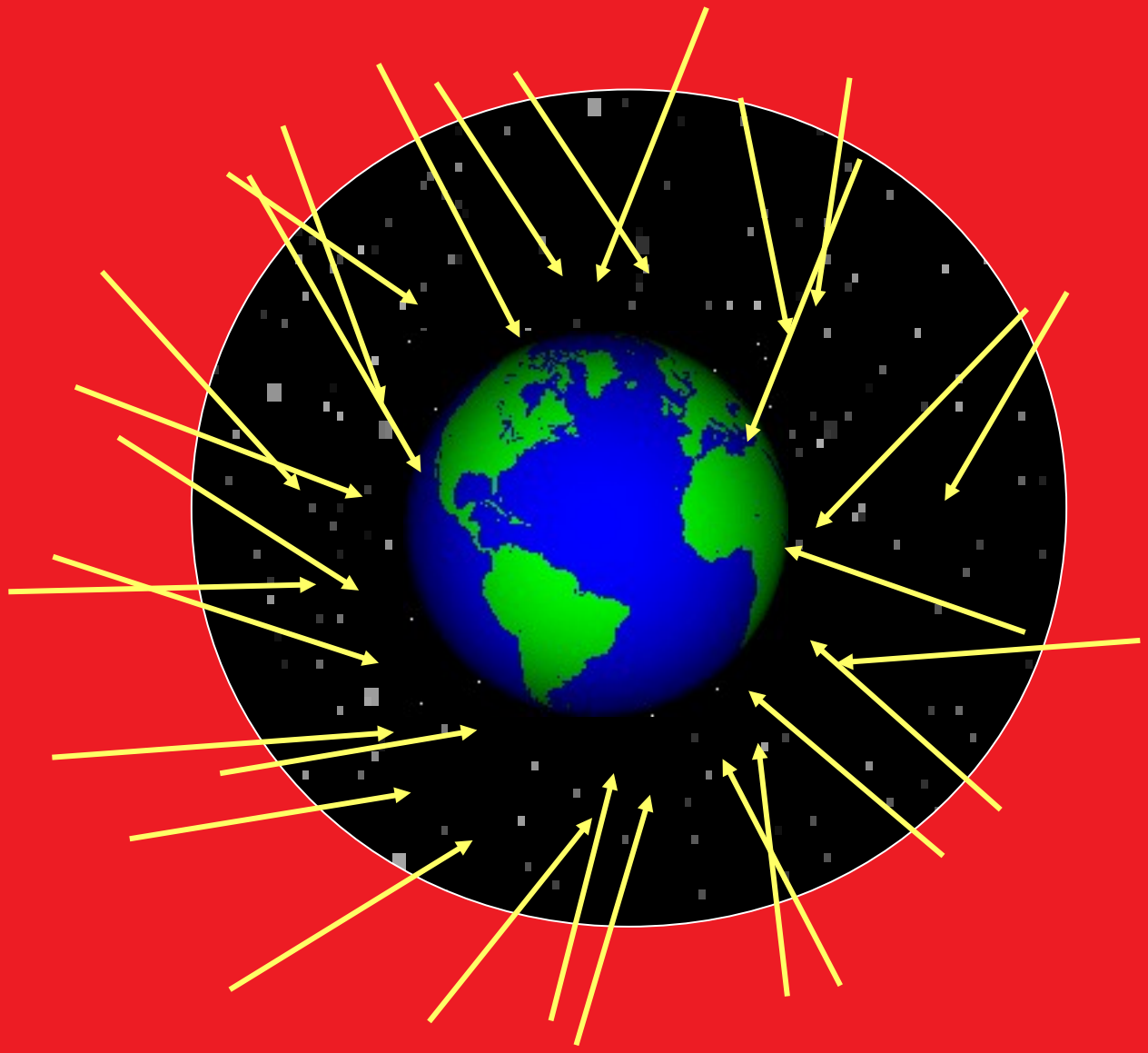
Extreme Energy Events

A (very) brief introduction

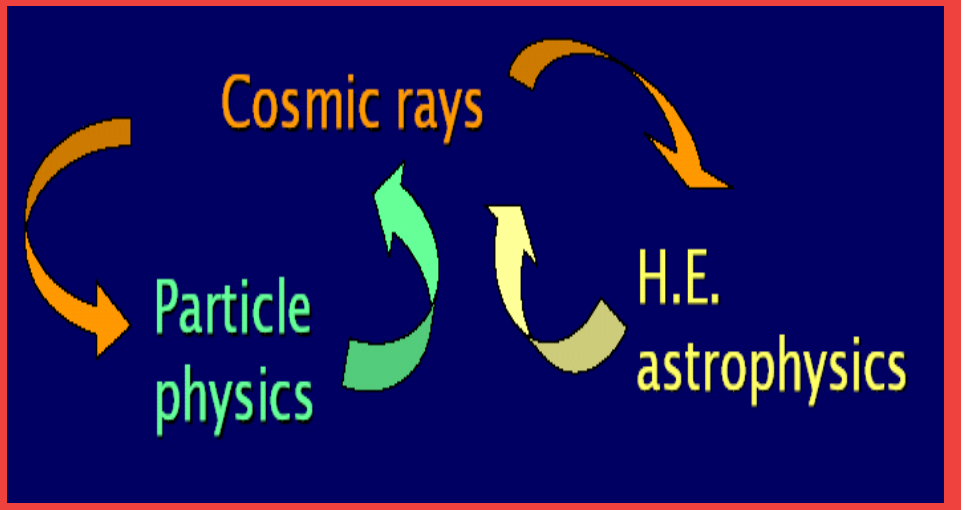
2021-04 online Meeting

Why
Extreme Energy Events

It's a long journey
In time and space...



Victor Hess after his 1912 balloon flight, during which he discovered cosmic rays from space. © National Geographic.



1927 Dimitry Skobelzyn
pictured the first tracks out of cosmic rays particles

1932 Carl Anderson

the POSITRON

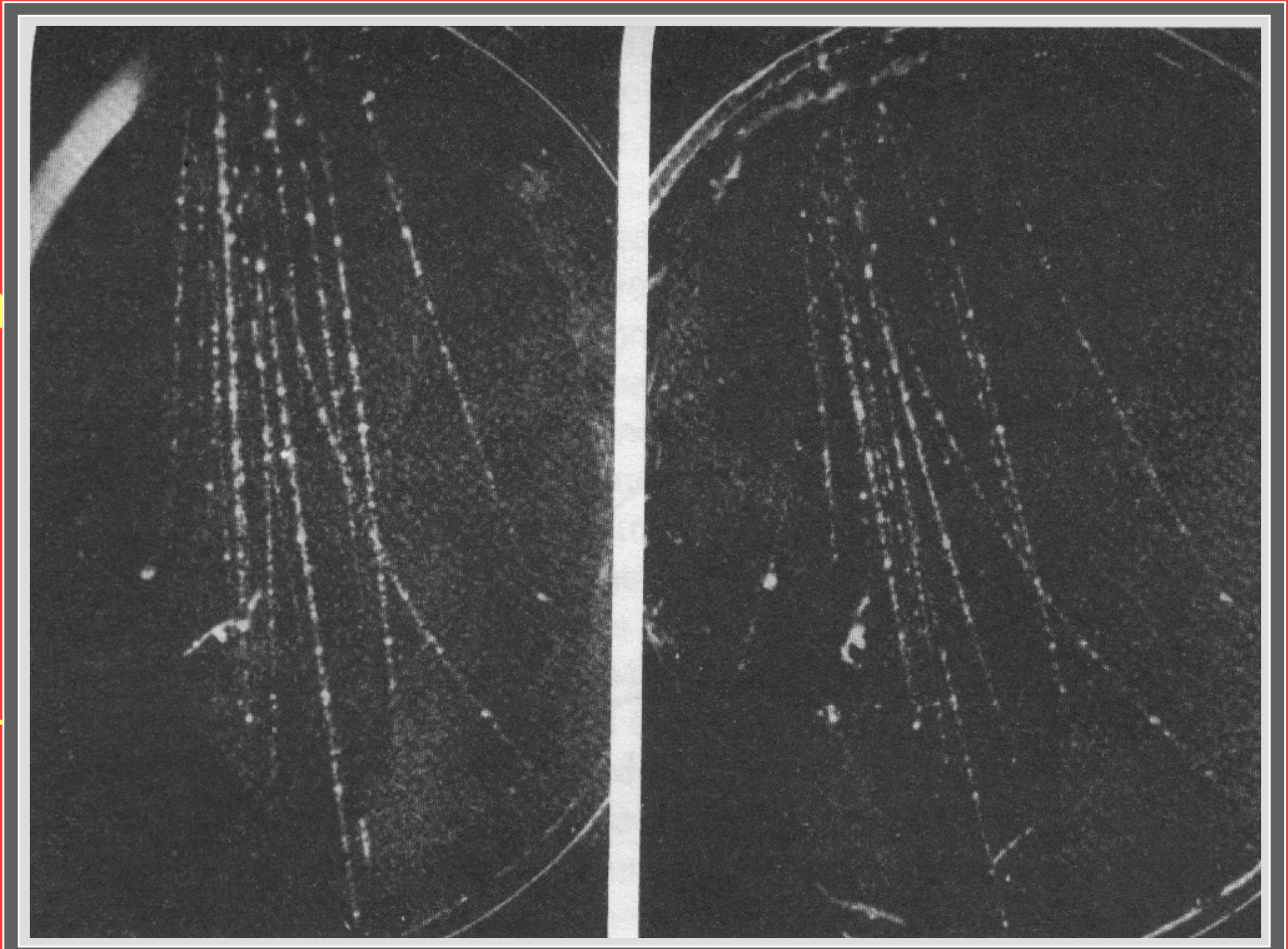
1933 Patrick Blackett

and Giuseppe Occhialini

POSITRON-ELECTRON
pair

1937 Seth Neddermeyer
and Carl Anderson

The MUON



Fotografia stereoscopica di uno sciame (P. Blackett & G. Occhialini, 1933)

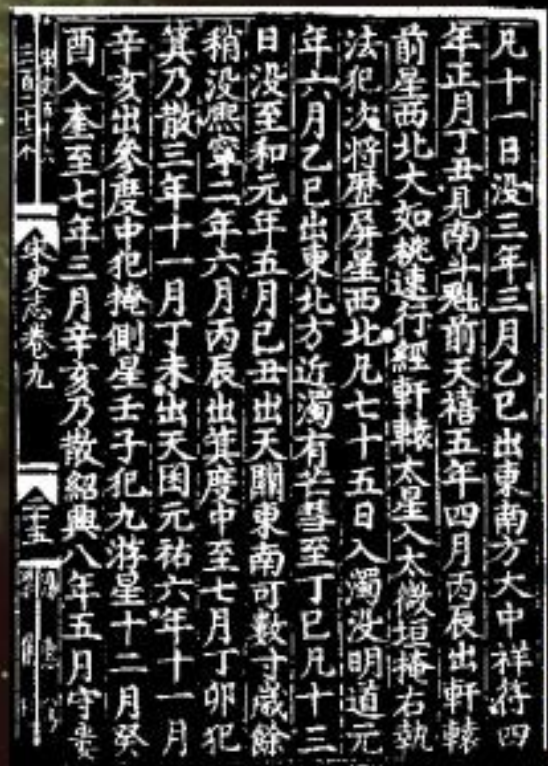
Nowadays the cosmic rays are fundamental tools to observe the far Universe in search for new Physics

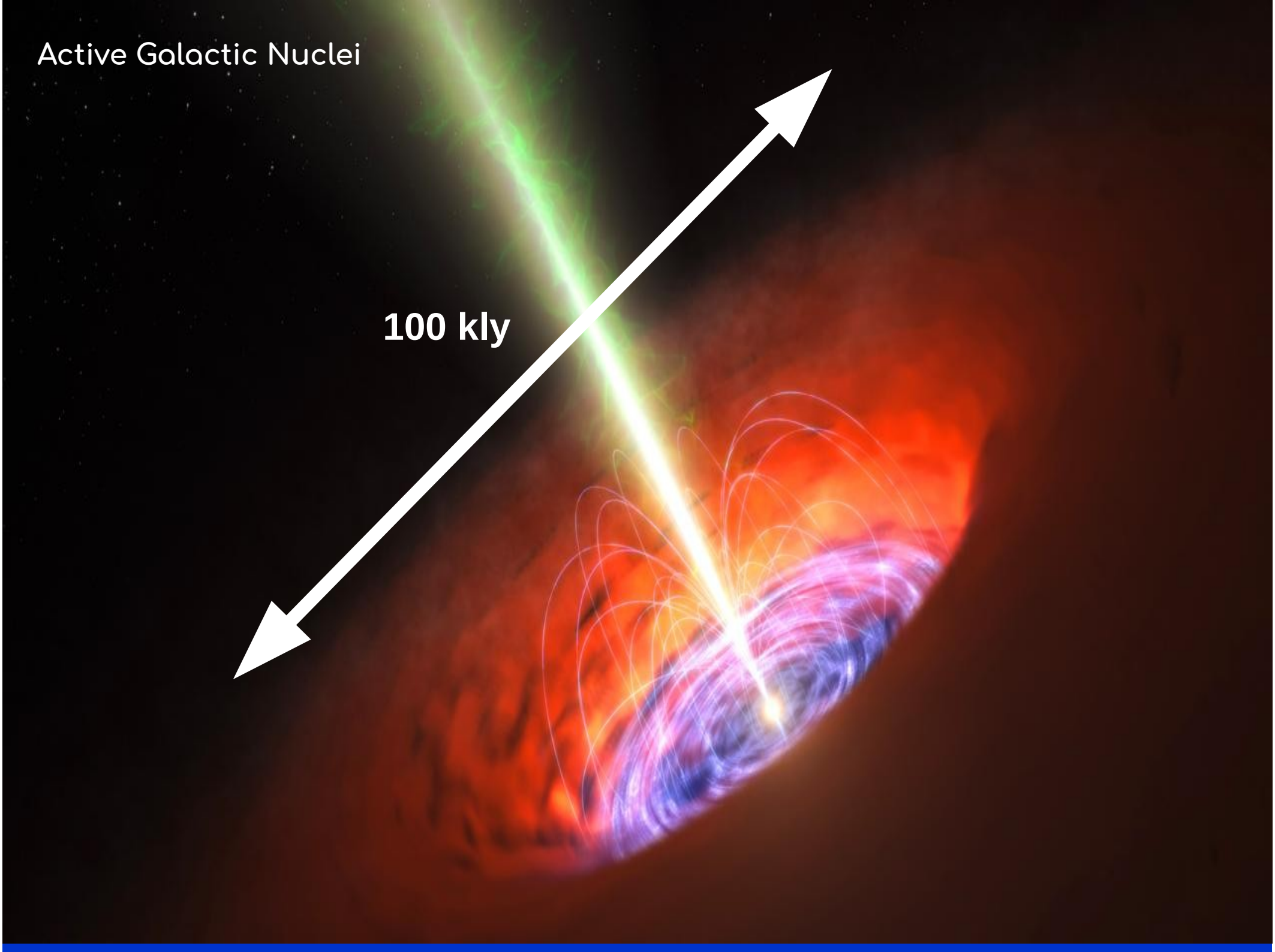
Crab Nebula (0bserved for the first time in 1054 DC in China)

A supernova remnants after the death of an ancient star

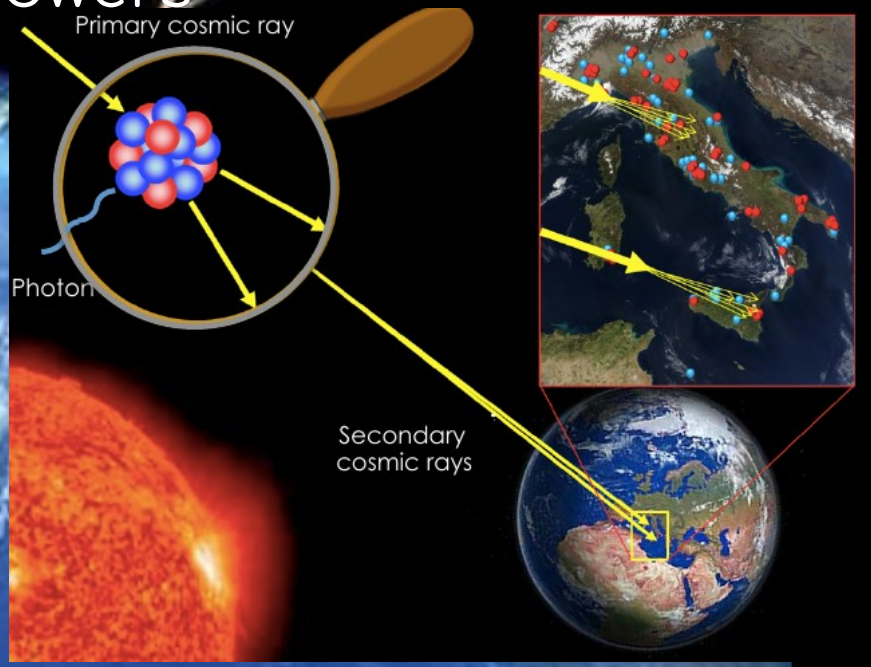
There heavy elements
are produced
and cosmic rays
are accelerated
by shock waves

5,5 ly


凡十一日没三年三月乙巳出東南方大中祥符四
年正月丁丑見南斗魁前天禧五年四月丙辰出軒轅
前星西北大如桃速行經軒轅太星入太微垣掩右執
法犯次將歷屏星西北凡七十五日入濁没明道元
年六月乙巳出東北方近濁有芒彗至丁巳凡十三
日没至和元年五月己丑出天關東南可數寸歲餘
稍没熙寧二年六月丙辰出井度中至七月丁卯犯
軍乃散三年十一月丁未出天囷元祐六年十一月
辛亥出參度中犯掩側星壬子犯九游星十二月癸
酉入畢至七年三月辛亥乃散紹興八年五月守
宋史志卷九
五


Active Galactic Nuclei
100 kly

EEE is an extended and inhomogeneous array for the search of Long Distance Correlations Extensive Air Showers



+ solar activity-CR relation
+ EAS study
+ CR anisotropies
+ climate-CR relations

Expected by several models

- Nuclei photodisintegration
- Massive Dark Matter
- topological defects
- many others ....

Present status:

Total **60** telescopes

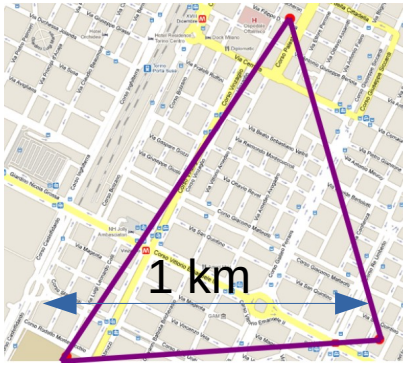
54 inside high schools buildings

2 at CERN

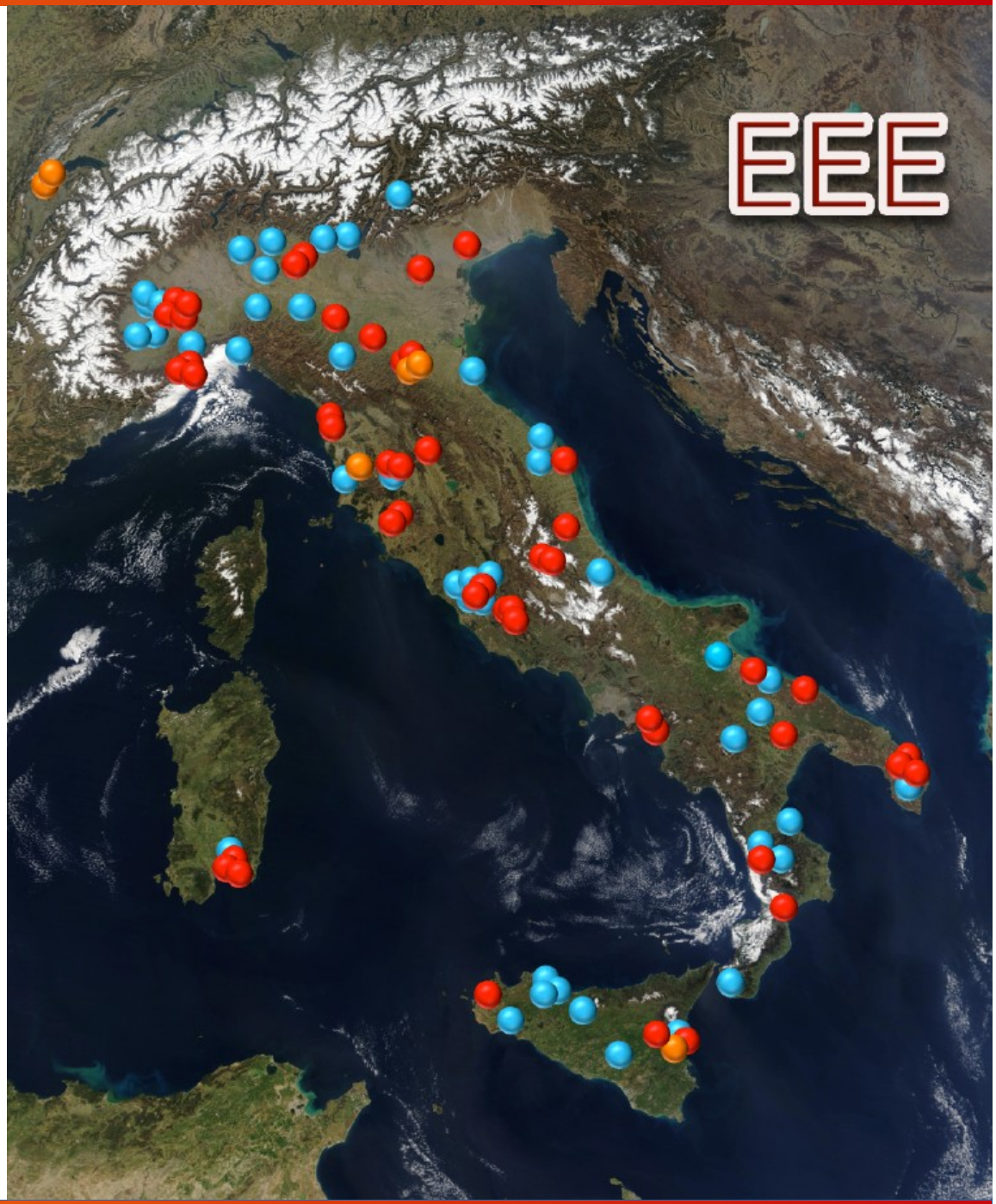
4 inside INFN and Universities

over a surface of **3 10^5 km^2**

covering
10° in latitude and longitude



Mostly organized
In 12 clusters
for EAS detection



The Multigap Resisitve Plate Chamber (see M.P. Panetta talk)

Same technology used for the Time Of Flight (TOF) measurement at ALICE (LHC)

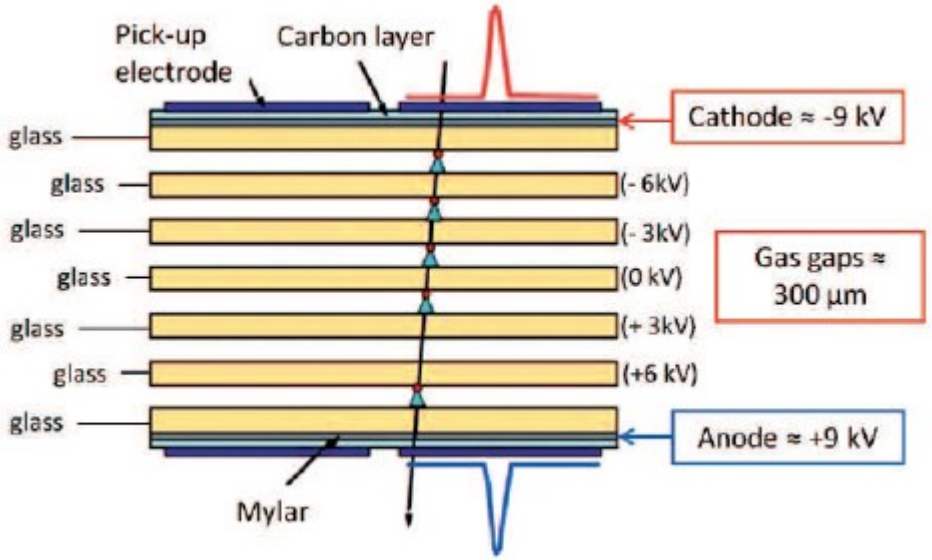
6 gas gaps 250-300 μm

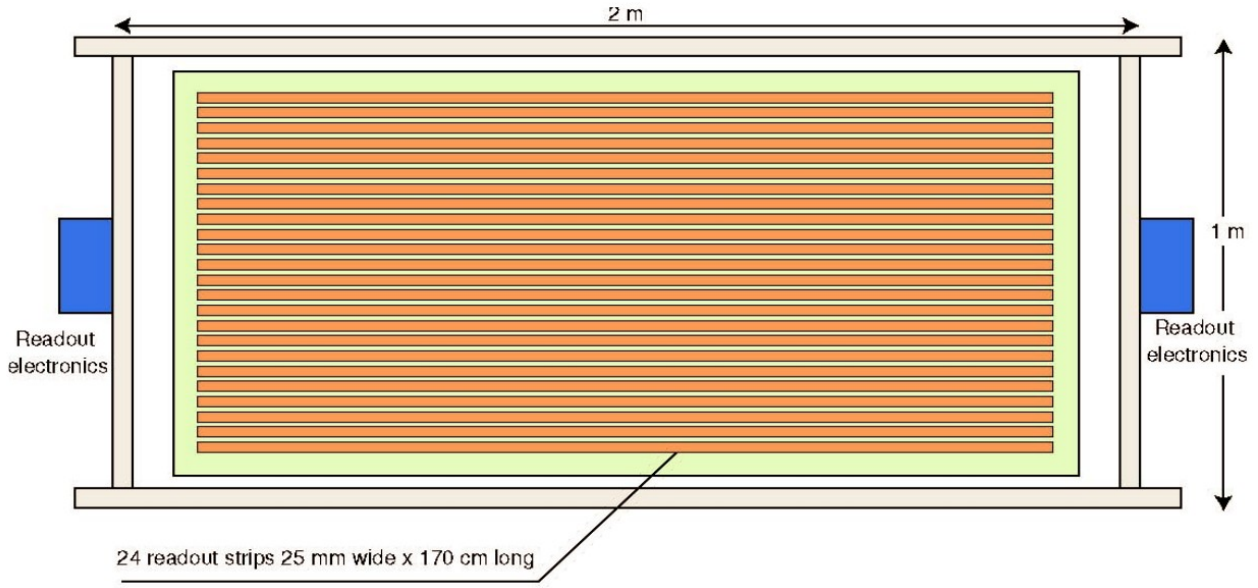
$C_2H_2F_4$ (98%) / SF_6 (2%) mixture

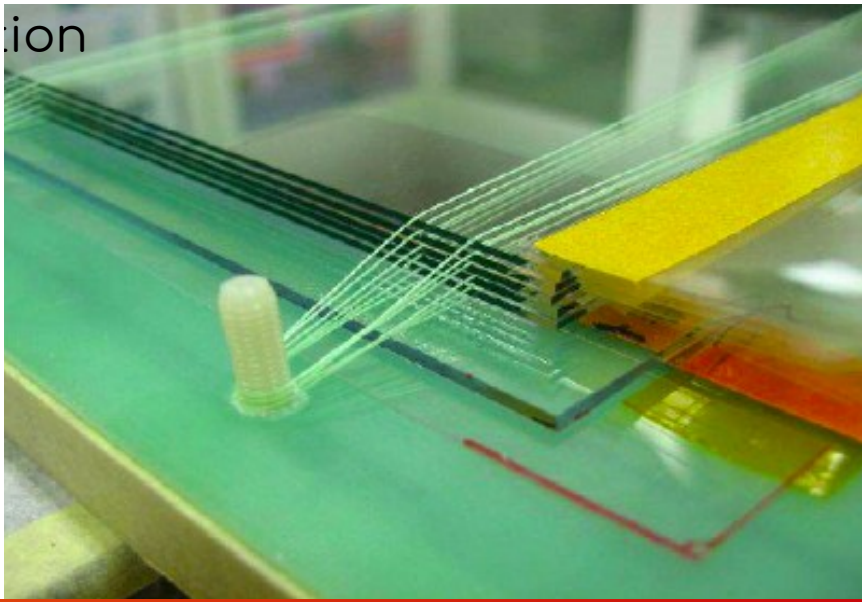
18-20 kV working voltage

24 strips per chamber, 2.5 cm pitch

The signal induced on the strips is the sum of the 6 gaps signals



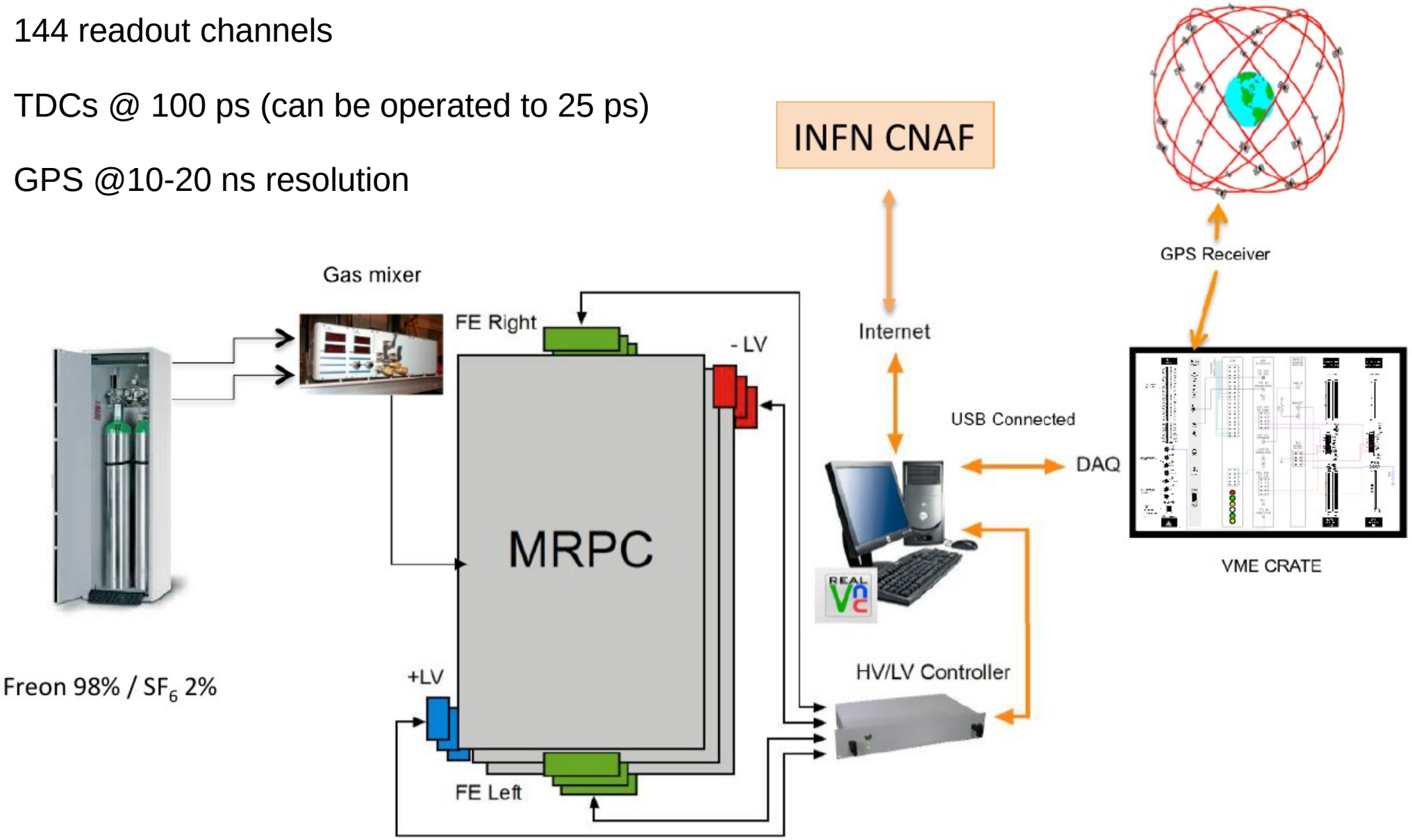




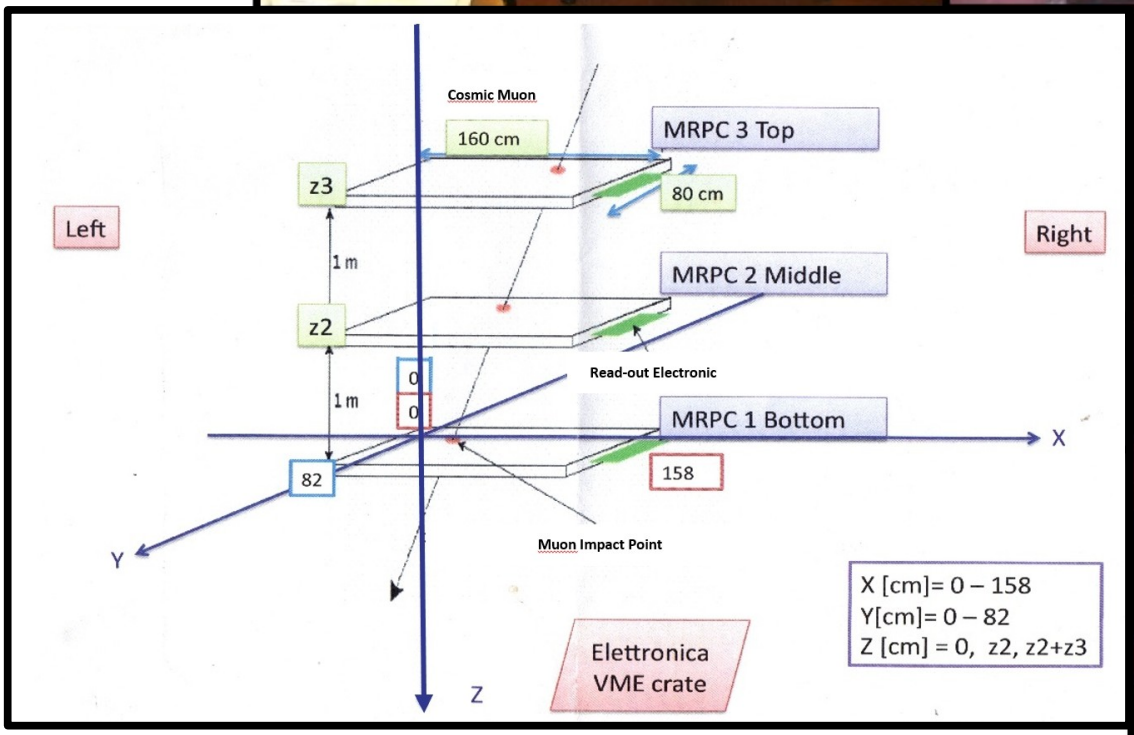
144 readout channels

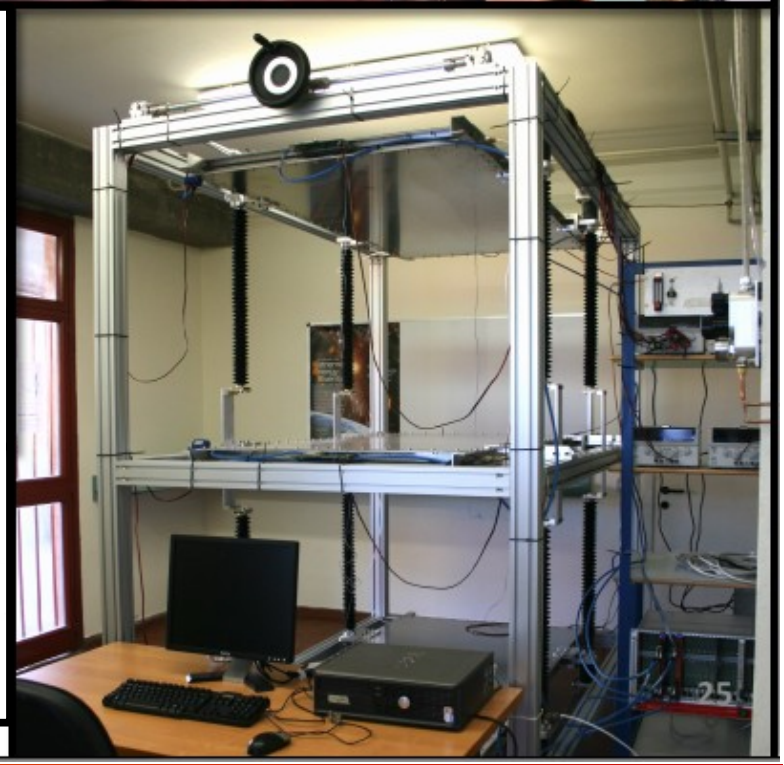
TDCs @ 100 ps (can be operated to 25 ps)

GPS @10-20 ns resolution

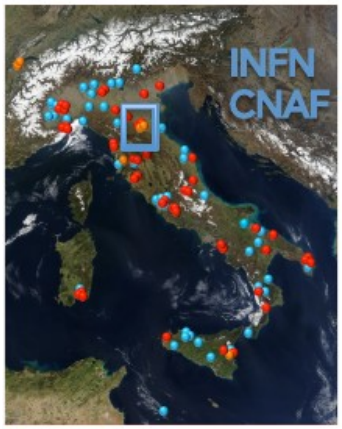


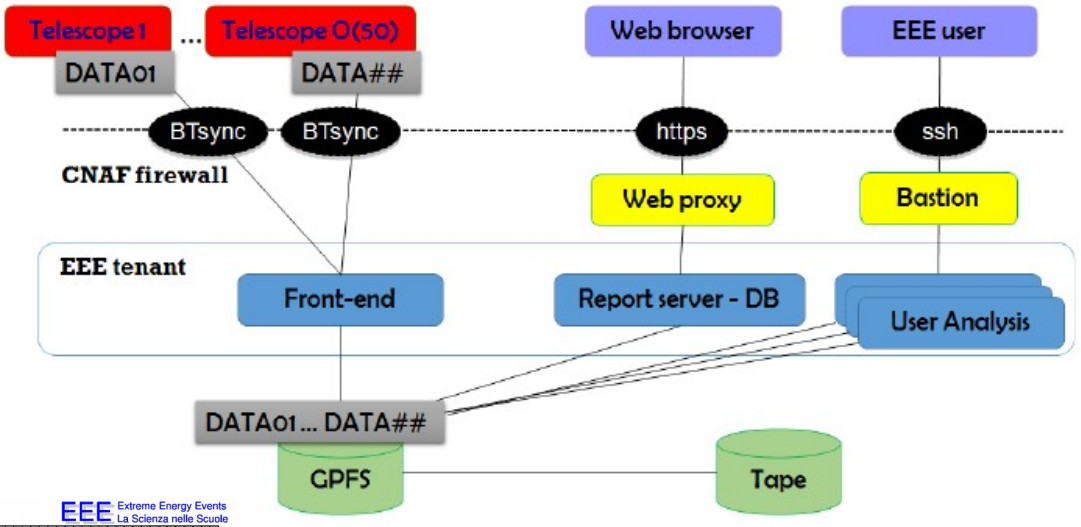
Some EEE telescope installations

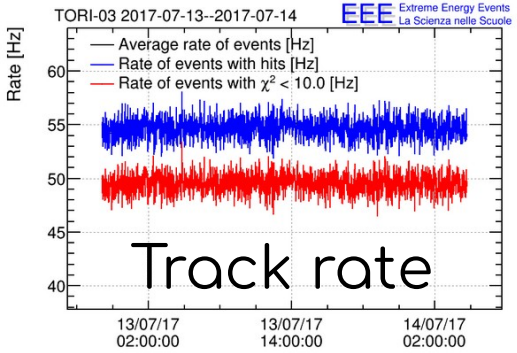


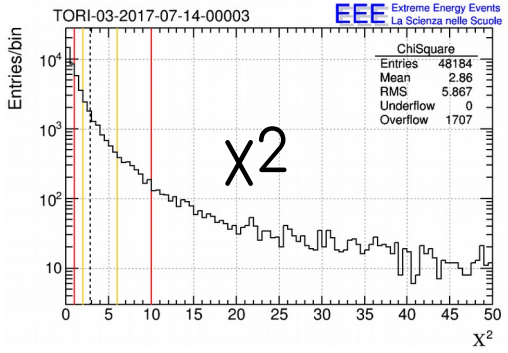


Data are automatically sent to INFN CNAF, reconstructed and processed by DQM

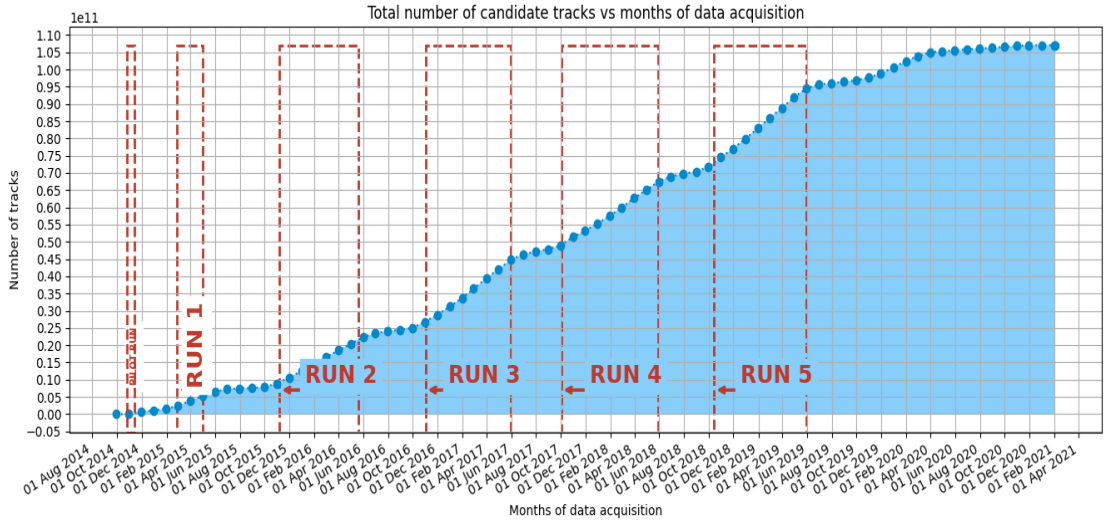








> 100 billions tracks
with χ2 < 10
have been collectected
for analysis



E.E.E.

How to make a clever use of the DATA QUALITY MONITOR

(and understanding the path to a discovery)

2021-04 EEE online Meeting

OUTLOOK

The path to a scientific discovery is a long, arduous and intricated.
Each step hides unknown sources of mistake.
Human inclination to crave for understanding the Universe is as well a strong source of will-driven mirages.

Let’s try to a make the path together, step by step

Data Quality Monitoring (DQM)

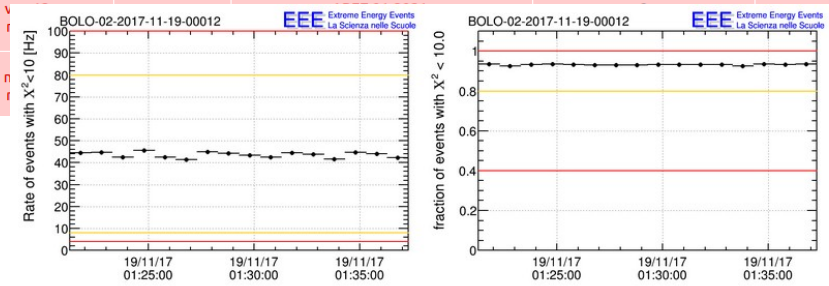
Insights

DQM

NETSTATUS

Telescopes status

School	Day	Time	Name of the last trasferred File	Number of Files trasferred today	Last Entry in the e-logbook of the Schools	Name of the last File analyzed by DQM	DQM daily report	RATE of Triggers for the last Run in DQM	RATE of Tracks for the last Run in DQM	Link DQM
ALTA-01 *[Event Display]*	sab 15 febbraio	11:08	ALTA-01-2020-02-15-00032.bin	0 *[History]*	*	ALTA-01-2020-02-15-00032.bin	*	31.0	10.0	ALTA-01
ANCO-01 *[Event Display]*	dom 08 marzo	19:08	ANCO-01-2020-02-25-00002.bin	0 *[History]*	*	ANCO-01-2020-02-25-00022.bin	*	22.0	15.0	ANCO-01
AREZ-01 *[Event Display]*					*	AREZ-01-2021-03-12-00004.bin	*	14.0	11.0	AREZ-01
BARI-01 *[Event Display]*					*	BARI-01-2021-03-16-00012.bin	*	10.0	9.0	BARI-01



RUN SUMMARY

- DST file path: /home/noferini/recoold/temp2/BOLO-02-2017-11-19-00012_dst.root
- Unique run identifier: 6397500012
- Smallest event timestamp: 343448477.007 s UTC
- Largest event timestamp: 343449500.929 s UTC
- Run duration (largest - smallest timestamp): 1023.923 s
- Total number of events: 47932
- Number of events with hits: 47912
- Number of events with a track: 44637
- Number of "no hits" (GPS?) events: 20
- Number of "no hit" events: 20
- Number of malformed events: 0
- Number of events out of order: 1

WEATHER STATION

- Readout at 343448400.000 s UTC (77.007 s before the start of the run)
- Outdoor temperature: 9.00 deg C
- Indoor temperature: 21.00 deg C
- Pressure: 1008 hPa

ALARM SUMMARY

Plot	Alarm	Status	Output	Limits
RateHitEvents	y_values	Clean	48.67 +- 0.89	[4 / 8 – 80 / 100]
DeltaTime	exp_fit_lambda	Clean	46.97 +- 0.22	[4 / 8 – 80 / 100]
HitMultTop	x_average	Clean	1.4788 +- 0.0036	[0.500 / 0.750 – 2 / 3]
HitMultMid	x_average	Clean	1.3551 +- 0.0034	[0.500 / 0.750 – 2 / 3]
HitMultBot	x_average	Clean	1.4167 +- 0.0034	[0.500 / 0.750 – 2 / 3]
HitMultTotal	x_average	Clean	4.2499 +- 0.0074	[1.50 / 2.50 – 6 / 9]
ClusterMultTop	x_average	Clean	1.0924 +- 0.0020	[0.500 / 0.750 – 2 / 3]
ClusterMultMid	x_average	Clean	1.0924 +- 0.0021	[0.500 / 0.750 – 2 / 3]
ClusterMultBot	x_average	Clean	1.0928 +- 0.0020	[0.500 / 0.750 – 2 / 3]
ClusterMultTotal	x_average	Clean	3.2760 +- 0.0048	[1.50 / 2.50 – 6 / 9]
ChiSquare	x_average	Warning	1.718 +- 0.018	[1 / 2 – 6 / 10]
RateTrackEvents	y_values	Clean	41.51 +- 0.82	[4 / 8 – 80 / 100]
FractionTrackEvents	y_values	Clean	0.9358 +- 0.0046	[0.400 / 0.800 – 1 / 1]
Phi				

ANCO-01 DQM list

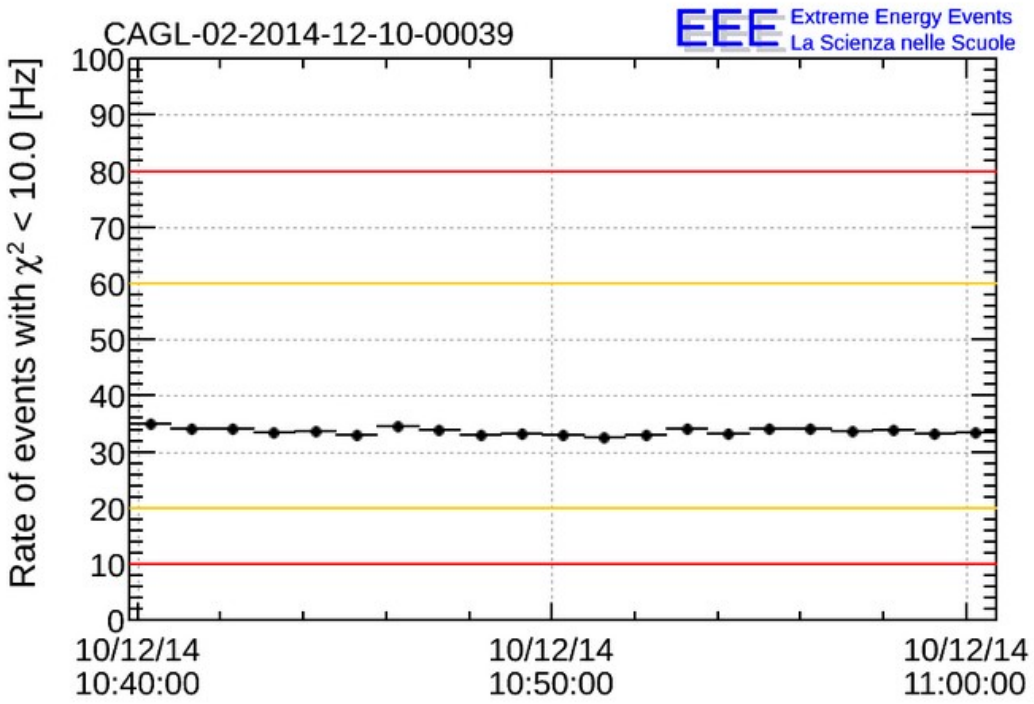
2020-02-25	2020-02-12	2020-02-11	2020-02-10	2020-02-09
2020-02-08	2020-02-07	2020-02-06	2020-02-05	2020-02-04
2020-02-03	2020-02-02	2020-02-01	2020-01-31	2020-01-30
2020-01-29	2020-01-25	2020-01-24	2020-01-23	2020-01-22
2020-01-21	2020-01-18	2020-01-17	2020-01-16	2020-01-15
2020-01-14	2020-01-13	2020-01-12	2020-01-11	2020-01-10
2020-01-09	2020-01-08	2020-01-07	2020-01-06	2020-01-05
2020-01-04	2020-01-03	2020-01-02	2020-01-01	2019-12-31
2019-12-30	2019-12-29	2019-12-28	2019-12-27	2019-12-26
2019-12-25	2019-12-24	2019-12-23	2019-12-22	2019-12-21
2019-12-20	2019-12-19	2019-12-18	2019-12-17	2019-12-16
2019-12-15	2019-12-14	2019-12-13	2019-12-12	2019-12-11
2019-12-10	2019-12-09	2019-12-08	2019-12-07	2019-11-30
2019-11-29	2019-11-28	2019-11-27	2019-11-26	2019-11-25
2019-11-24	2019-11-23	2019-11-22	2019-11-21	2019-11-20
2019-11-17	2019-11-16	2019-11-15	2019-11-14	2019-11-13
2019-11-12	2019-11-11	2019-11-10	2019-11-09	2019-11-08
2019-11-07	2019-11-06	2019-11-05	2019-11-04	2019-11-03
2019-11-02	2019-11-01	2019-10-31	2019-10-30	2019-10-29
2019-10-28	2019-10-27	2019-10-25	2019-10-24	2019-10-23
2019-10-22	2019-10-21	2019-10-20	2019-10-19	2019-10-18
2019-10-17	2019-10-16	2019-10-15	2019-10-14	2019-09-13

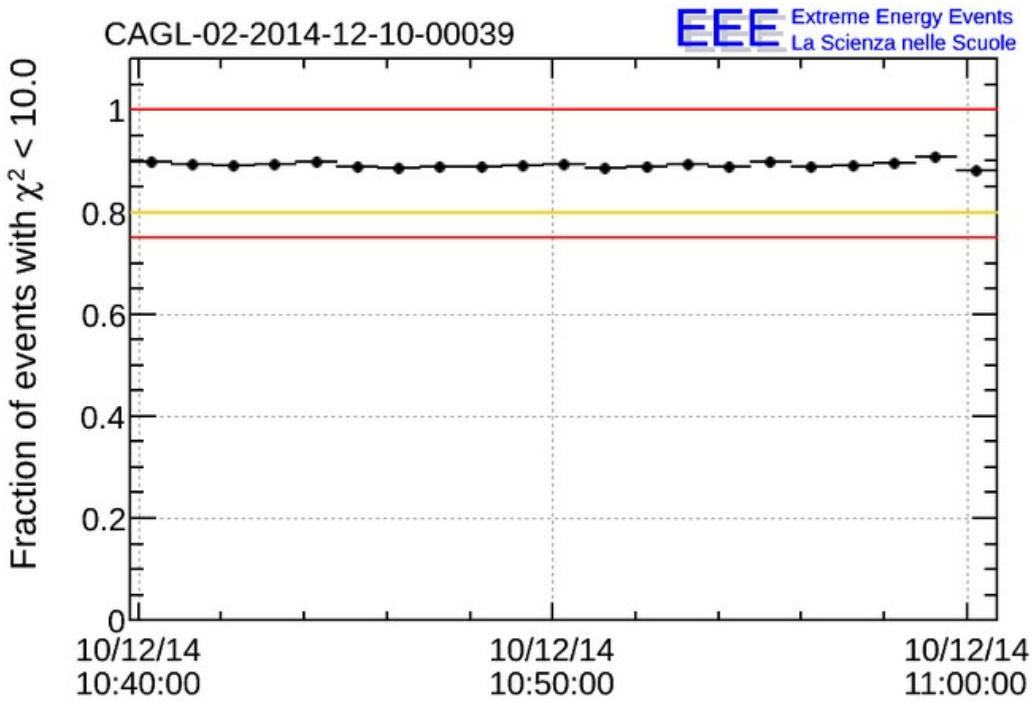
DQM

RUN DQM

Run quality

EEE DQM run report





Good tracks rate χ2<10

Fraction of good events
(with a good track)

DQM

RUN DQM

Run quality

Run summary

- DST file path: /home/analisi/eeetmp/CAGL-02-2014-12-10-00039_dst.root
- Unique run identifier: 10290000039
- Smallest event timestamp: 250601988.021 s UTC
- Largest event timestamp: 250603243.596 s UTC
- Run duration (largest - smallest timestamp): 1255.575 s
- Total number of events: 50000
- Number of events with hits: 47341
- Number of events with a track: 42232
- Number of "no hits" (GPS?) events: 2520
- Number of "no hit" events: 139
- Number of malformed events: 0
- Number of events out of order: 0

Secondi dal 1/1/2007

Weather station

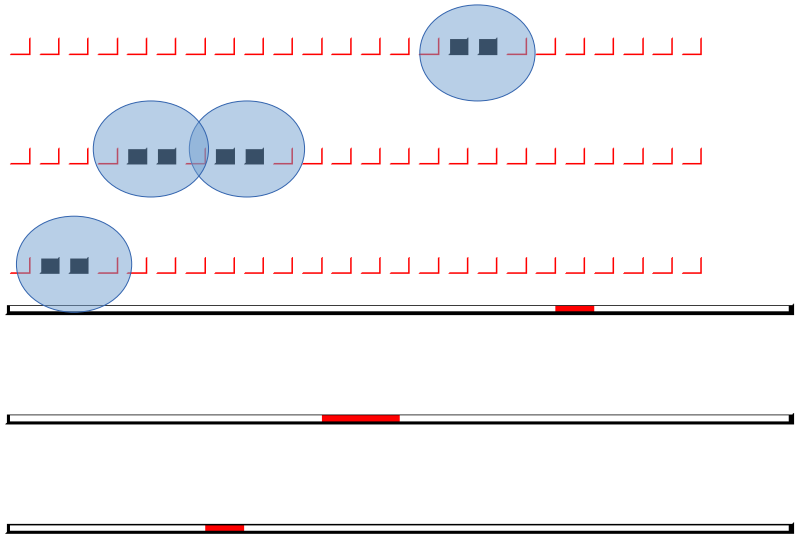
- Readout at 250600800.000 s UTC (1188.021 s before the start of the run)
- Outdoor temperature: 14.60 deg C
- Indoor temperature: 23.90 deg C
- Pressure: 1018 hPa

DQM

RUN DQM

DQM histograms and alarms
Plenty of information
not to be left unused!

Run quality



ALARM SUMMARY

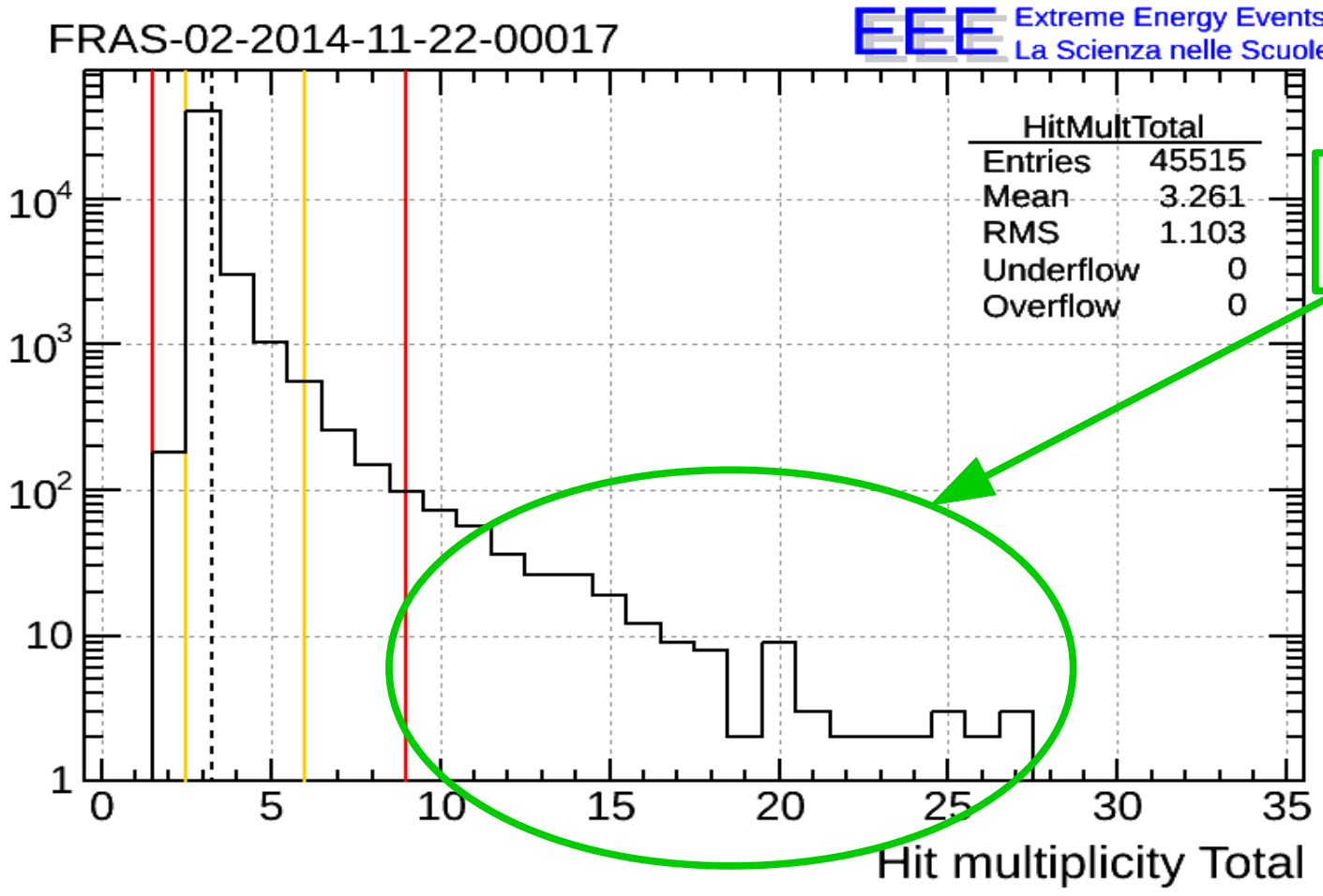
PLOT	ALARM	STATUS	OUTPUT	LIMITS
RateHitEvents	y_values	Clean	31.41 +- 0.72	[10 / 20 – 60 / 80]
DeltaTime	exp_fit_lambda	Clean	33.32 +- 0.16	[5 / 10 – 50 / 75]
HitMultTop	x_average	Clean	1.0810 +- 0.0019	[0.500 / 0.750 – 2 / 3]
HitMultMid	x_average	Clean	1.0925 +- 0.0021	[0.500 / 0.750 – 2 / 3]
HitMultBot	x_average	Clean	1.0929 +- 0.0021	[0.500 / 0.750 – 2 / 3]
HitMultTotal	x_average	Clean	3.2614 +- 0.0052	[1.50 / 2.50 – 6 / 9]
ClusterMultTop	x_average	Clean	1.0810 +- 0.0019	[0.500 / 0.750 – 2 / 3]
ClusterMultMid	x_average	Clean	1.0925 +- 0.0021	[0.500 / 0.750 – 2 / 3]
ClusterMultBot	x_average	Clean	1.0927 +- 0.0021	[0.500 / 0.750 – 2 / 3]
ClusterMultTotal	x_average	Clean	3.2662 +- 0.0052	[1.50 / 2.50 – 6 / 9]
ChiSquare	x_average	Clean	2.735 +- 0.020	[1 / 2 – 6 / 10]
RateTrackEvents	y_values	Clean	29.85 +- 0.70	[10 / 20 – 60 / 80]
FractionTrackEvents	y_values	Clean	0.9642 +- 0.0042	[0.750 / 0.800 – 1 / 1]
Phi				
Theta				
TimeOfFlight				
TrackLength				

DQM

RUN DQM

Run quality

HIT MULTIPLICITY
distribution



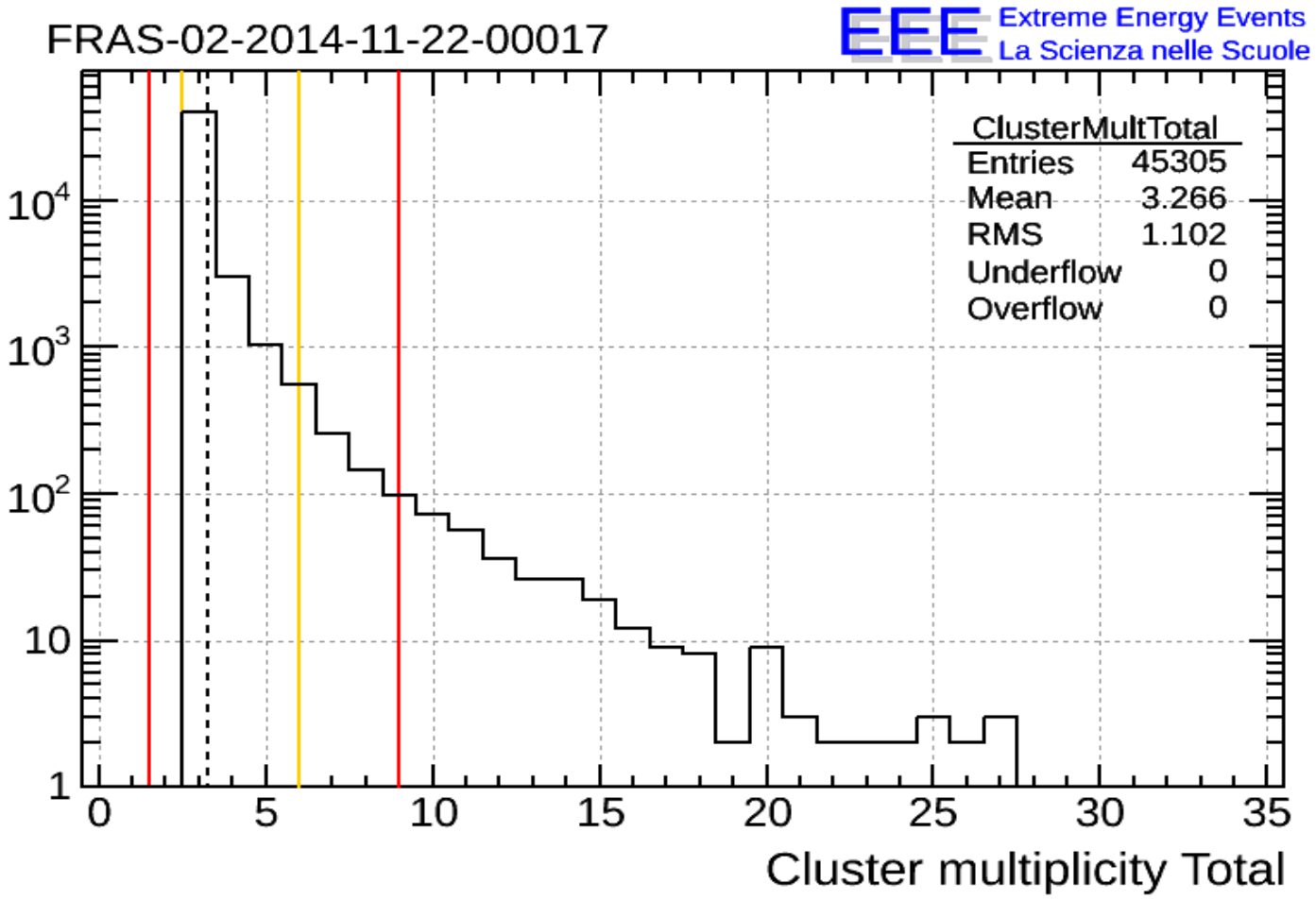
"noisy" events

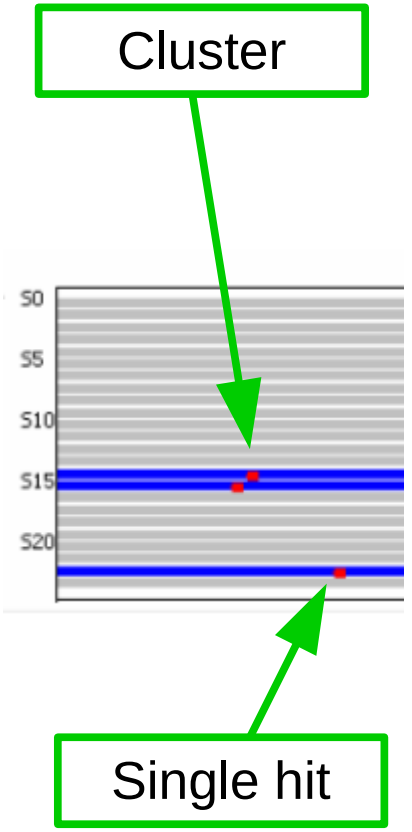
DQM

RUN DQM

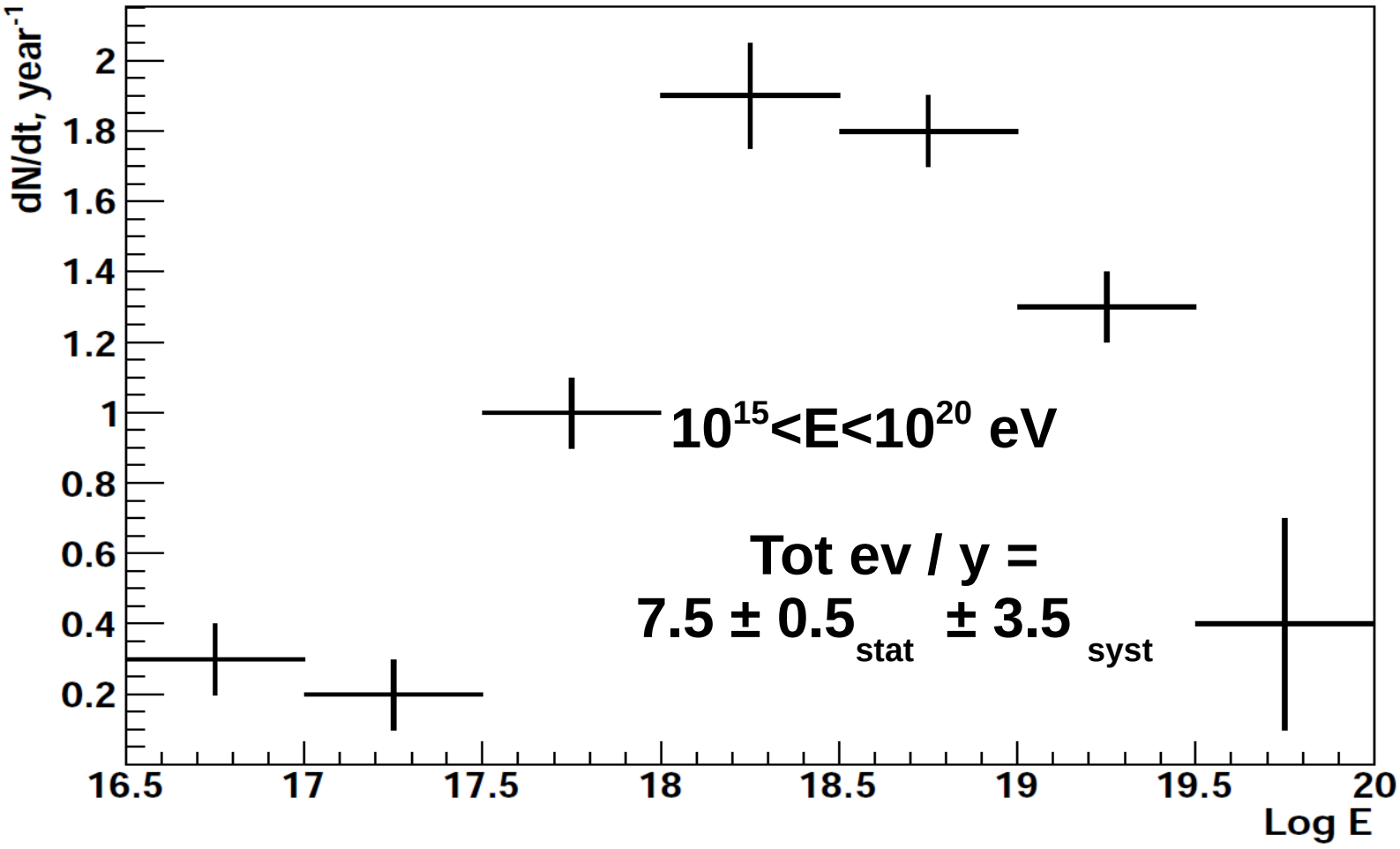
Run quality

CLUSTER MULTIPLICITY
distribution





Let’s start to think what we need to come to a measurement and (possibly) to a discovery



Insights

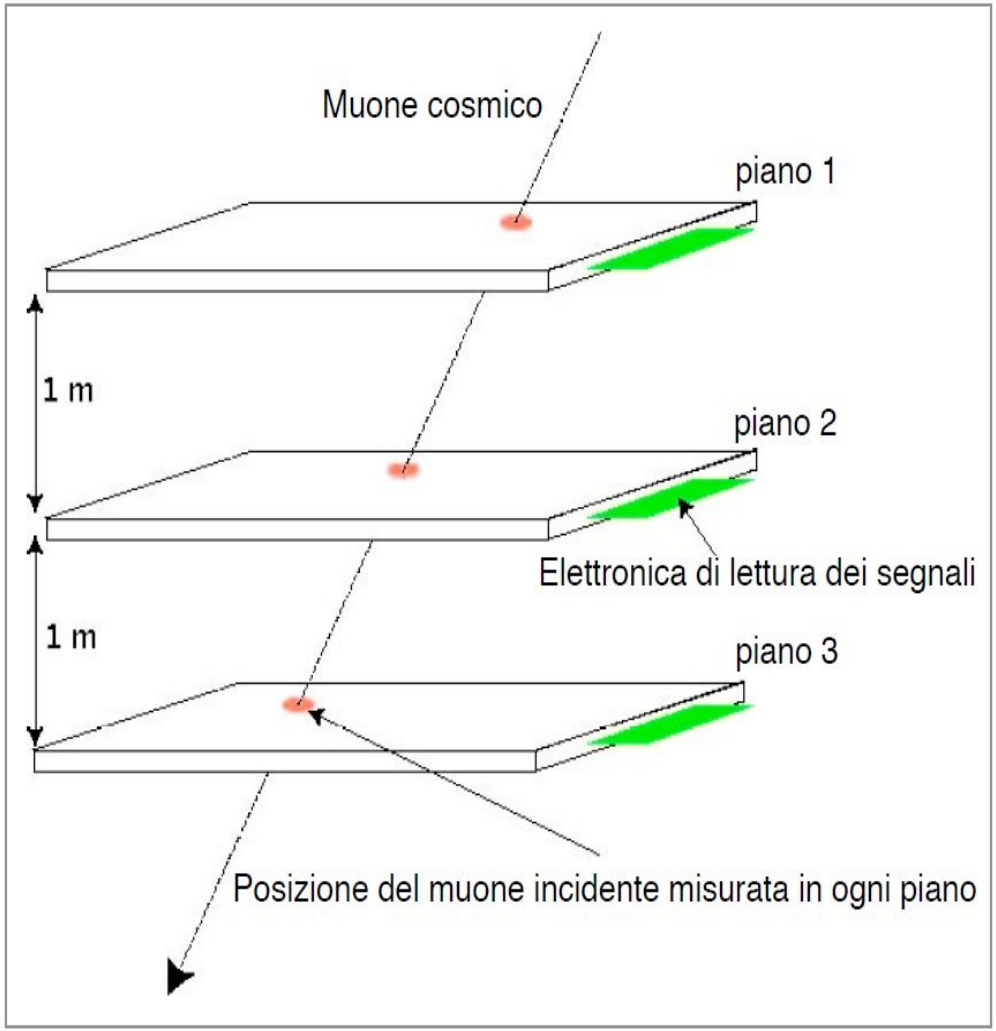
Two important parameters:
- the telescope efficiency
- the spurious coincidence rate

The **efficiency** is the Probabilty for a MRPC to detect a particle. On a high amount of particles travelling across a chamber the efficiency is

Eff =

N of particles detected

Number of particles actually travelled through the chamber



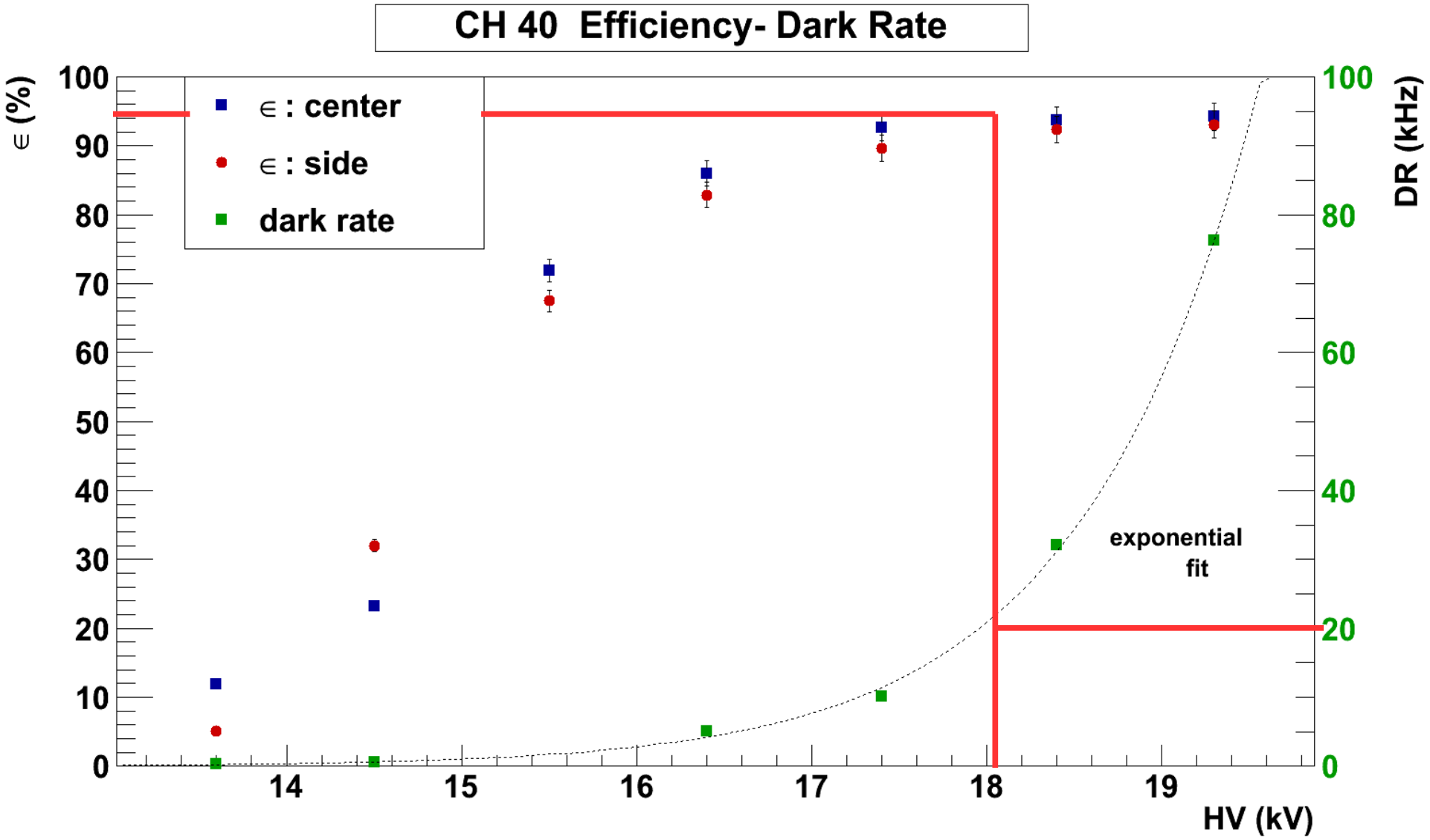
The **spurious rate** is the rate of signals seen by a MRPC (or a telescope) NOT CORRELATED with a real particle passing through the MRPC.

Insights

Dark Rate & Efficiency

A telescope WORKING POINT:

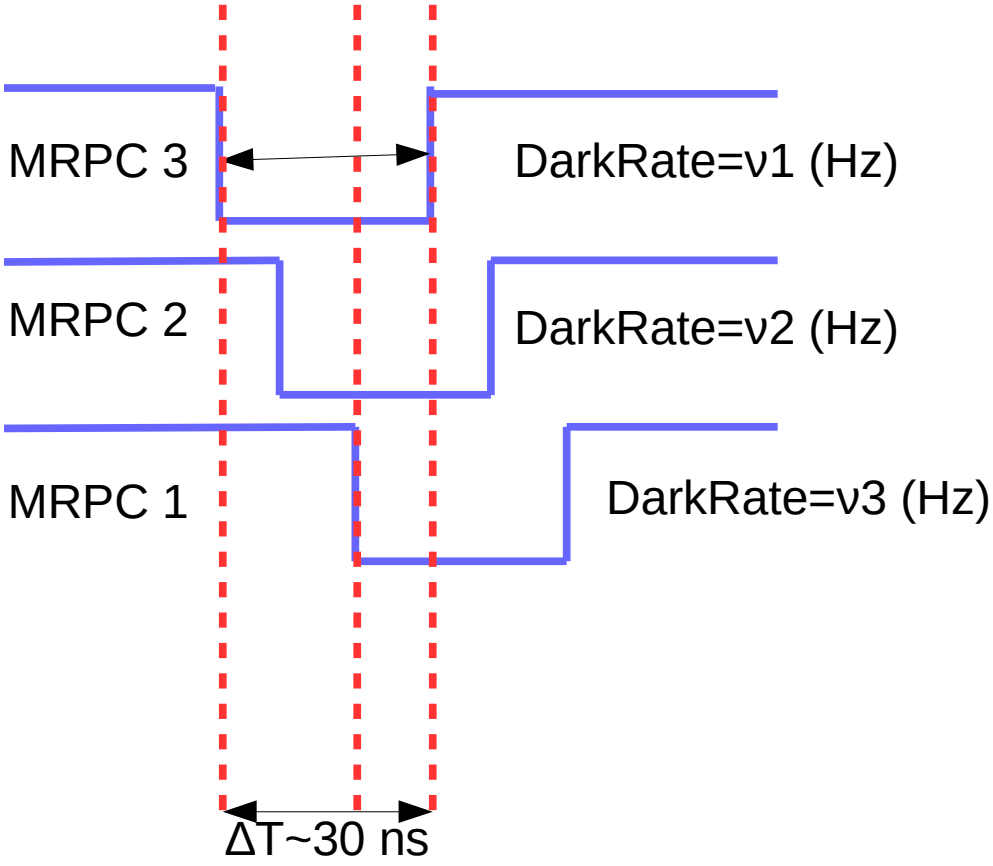
- Efficiency
- Dark Rate (DR)



Insights

Spurious coincidences for a set of MRPC of a EEE telescope

Dark Rate & Spurious



The time window keeps into account

- **Signal speed** along the strips (20 ns)
- **Time of Flight** between chambers

$P(A \cap B)=P(A)P(B)$ non correlated

Spurios coincs in MRPC 2 in ΔT

$\nu_2 \cdot \Delta T$

Spurious coincs in MRPC 3 in ΔT

$\nu_3 \cdot \Delta T$

Spurious rate:

$$\nu(\text{doubles}) = 2 \cdot (\nu_1 \cdot \Delta T) \cdot (\nu_2 \cdot \Delta T)/\Delta T = 2 \cdot \nu_1 \cdot \nu_2 \cdot \Delta T$$

$$\nu(\text{triples}) = 3 \cdot \nu_1 \cdot \nu_2 \cdot \nu_3 \cdot \Delta T^2$$

$$\sim 3 \cdot (2 \cdot 10^4\ \text{Hz})^3 \cdot (2 \cdot 10^{-8}\ \text{s})^2 = \sim 10^{-2}\ \text{Hz}$$

Coincidences are fundamental tool to decrease the rate of spurious and allowing for the observation of real particles

Insights

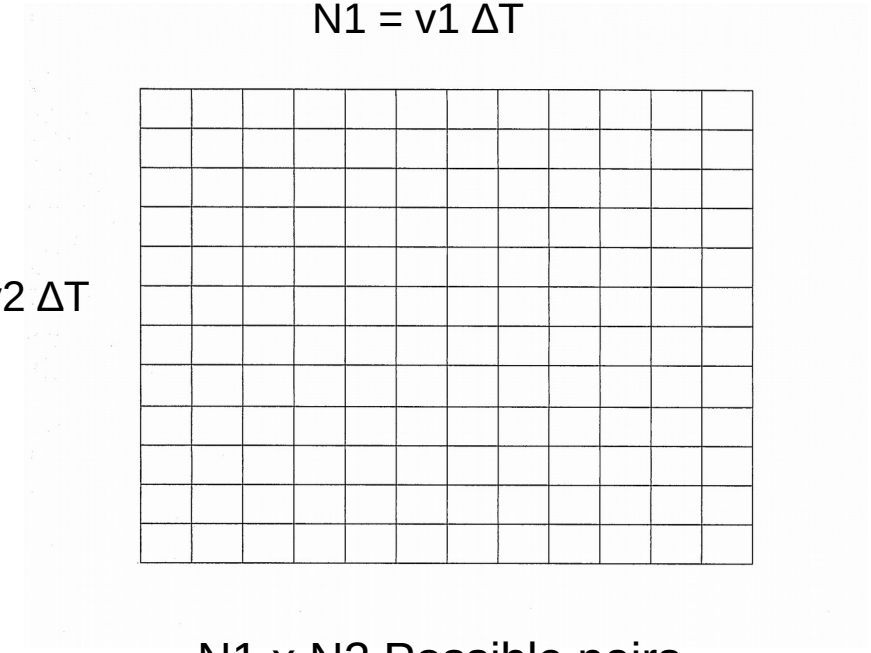
Dark Rate & Spurious

$$\nu(\text{Ntuples}) = N \cdot \nu 1 \cdot \nu 2 \cdot \nu 3 \cdot \ldots \nu N \times \Delta T^{N-1}$$

where N comes from the firing MRPCs

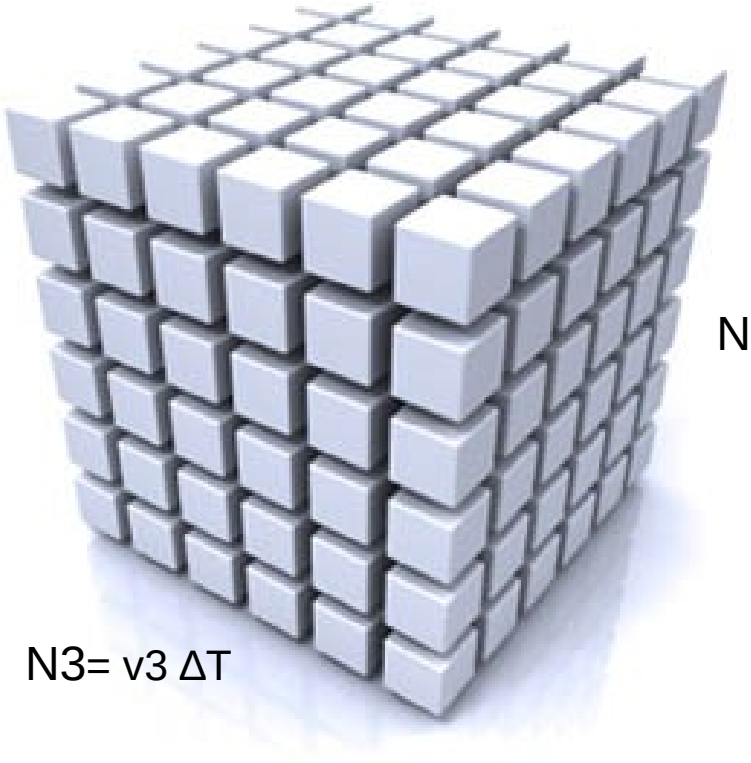
N1 = v1 ΔT

N2= v2 ΔT



N1 x N2 Possible pairs

N1 = v1 ΔT



N2= v2 ΔT

N3= v3 ΔT

N1 x N2 x N3 Possible triples

Hands on!

Dark Rate & Spurious

SpuriousCoincidences

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100% $ % .0 .00 123 Default (Ari... 10

F18

	A	B	C	D	E	F
1	**efficiency of 1 MRPC**	**Spurious rate**	**Nch**	**T**		**average muon rate**
2	0.9	1.00E+04	3	3.00E-08		100
3						
4						
5	**efficiency of a telescope**	**spurios triple rate**				
6	0.729	2.70E-03				

Try to:

- evaluate the spurious telescope rate as a function of N chambers per telescope
- evaluate the efficiency of a telescope as a function of N chambers per telescope

- make plots showing this two quantitites vs N

- study the good track/false triggers over 1 year of data taking vs N
----------Define a proposal: which is the optimal number of MRPC for a telescope?